Polarized 3D Active and Passive Radiative Transfer with Preferentially-Aligned Ice Particles

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BACKGROUND

To solve the vector radiative transfer equation, it must be represented in integral form

$$\mathbf{I}(\mathbf{n},\mathbf{s}_0) = \mathbf{O}(\mathbf{s}_N,\mathbf{s}_0)\mathbf{I}(\mathbf{n},\mathbf{s}_N) + \int_{\mathbf{s}_N}^{\mathbf{s}_0} \mathbf{O}(\mathbf{s}',\mathbf{s}_0)\times\left(\mathbf{K}_a(\mathbf{n}) + \int_{4\pi} \mathbf{Z}(\mathbf{n},\mathbf{n}')\mathbf{I}(\mathbf{n}')dn\right)ds'$$

The evolution operator gives the piecewise extinction matrix in the direction of propagation

$$\mathbf{O}(\mathbf{s}',\mathbf{s}) = e^{-\mathbf{K}_1\Delta s_1}e^{-\mathbf{K}_2\Delta s_2}\dots\ e^{-\mathbf{K}_n\Delta s_n}$$

and total propagation paths are determined when

$$r_n = \mathbf{O}(\mathbf{s}',\mathbf{s})$$

For passive sensors, reverse path tracing is employed for computation efficiency. However, since the initial polarization state of the photon is unknown, path lengths are determined using the first Stokes component I with subsequent conditioning of the PDF:

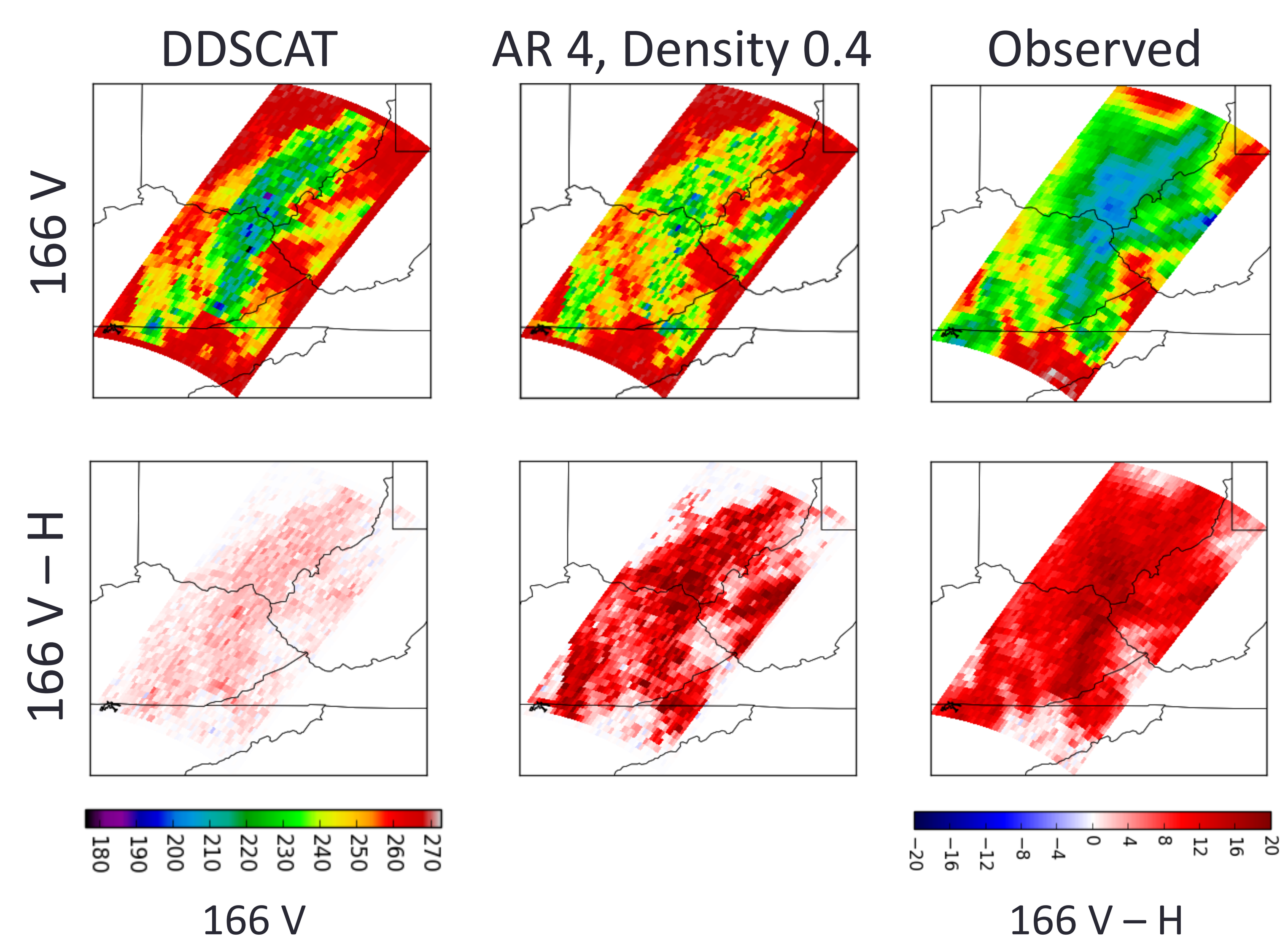
$$\mathbf{O}(\mathbf{s}_{i+1},\mathbf{s}_i) = O_{11}(\mathbf{s}_{i+1},\mathbf{s}_i)$$

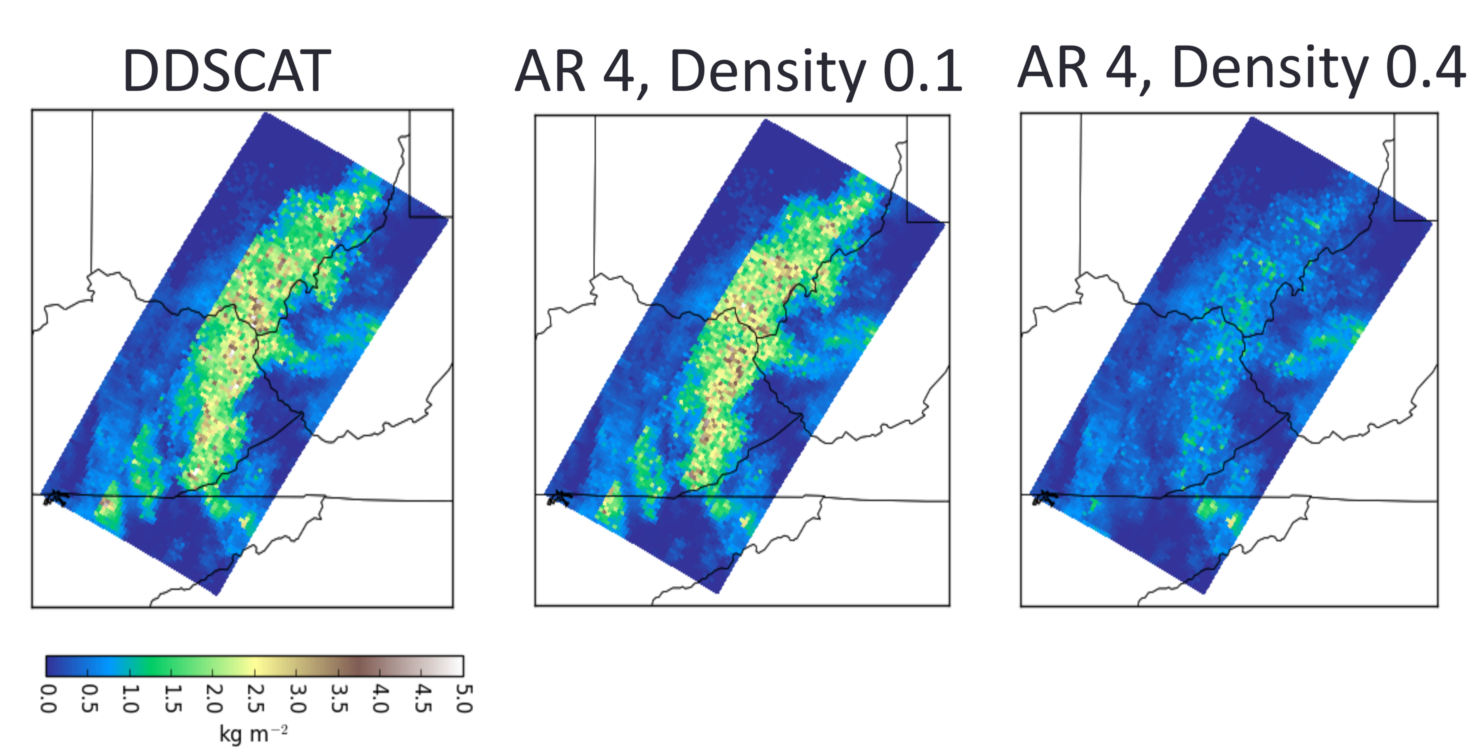
For active sensors, reverse path tracing does not offer computational efficiency since all photons can contribute to the reflectivity. Unlike with the passive case, where the second Stokes component Q is often an order of magnitude smaller than I, the first two Stokes components are of similar magnitude. When the extinction matrix is diagonal, the previous equation is valid. For a block diagonal extinction matrix (mean horizontal alignment), both I and Q must be considered:

$$\mathbf{O}(\mathbf{s}_{i+1},\mathbf{s}_i) = O_{11}(\mathbf{s}_{i+1},\mathbf{s}_i) + \frac{Q}{I}O_{12}(\mathbf{s}_{i+1},\mathbf{s}_i)$$

T_B POLARIZATION DIFFERENCE

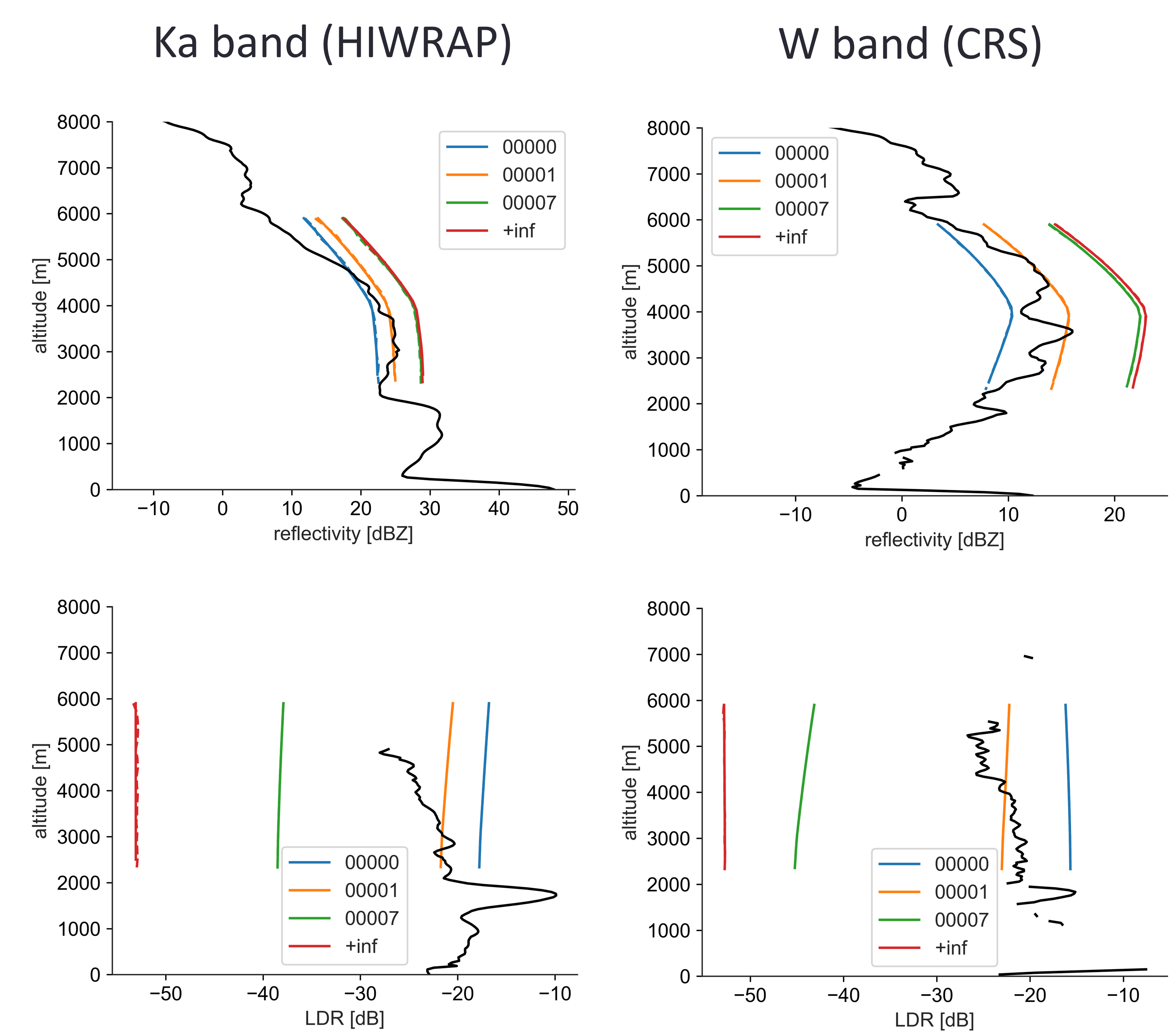
Using GPM combined retrievals, we looked at the induced polarization difference for horizontally-aligned T-Matrix spheroids and randomly-oriented DDSCAT aggregates. While the T-Matrix particles are capable of reproducing brightness temperature and polarization difference, the retrieved water content is far less than the quantity retrieved using the DDSCAT aggregates. However, there are currently no DDA databases for preferentially-aligned particles.





LINEAR DEPOLARIZATION RATIO

Looking at data from the ER-2 radar taken during OLYMPEX (CRS, and HIWRAP K_a band), we compare modeled profiles of reflectivity and LDR with observations for varying amounts of flutter, assuming planar crystal geometries (aspect ratio 7, T-Matrix calculations). Stable plates induce little depolarization, while increased flutter results in greater depolarization.



CONCLUSIONS

The radiative transfer model is capable of reproducing remote sensing observables for 3D scenes that include aligned, nonspherical ice particles. The dearth of aligned particles in current databases makes it difficult to properly diagnose polarized measurements. We are currently looking to apply the Invariant Imbedding T-Matrix method to produce the scattering properties of rotationally-symmetric particles with high aspect ratios and/or nonhomogeneous complex permittivities (see poster 206) to better model planar and columnar crystals with preferential alignment.